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TECHNICAL MEMORANDUM

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LONGITUDINAL AERODYNAMIC CHARACTERISTICS AT A MACH NUMBER OF 3.0 OF AN ARROW WING WITH BODIES OF CIRCULAR AND SEMICIRCULAR SECTIONS

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LONGITUDINAL AERODYNAMIC CHARACTERISTICS AT A MACH NUMBER OF 3.0 OF AN ARROW WING WITH BODIES OF CIRCULAR AND SEMICIRCULAR SECTIONS*

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SUMMARY

An experimental investigation was conducted to determine the longitudinal aerodynamic characteristics of an arrow wing with three body shapes: a parabolic body of revolution, a Sears-Haack body, and a von Kármán ogive body. Both symmetrically mounted circular-section bodies and bottom-mounted semicircular-section bodies were tested. The tests were conducted at a Mach number of 3.0 and at a Reynolds number, based on the wing reference chord, of 2.6×10^6. Angle of attack was varied from -4° to 11°.

The results indicated that for each body shape, changing from a circular-section body to a bottom-mounted semicircular-section body provided substantial positive increments in lift and pitching-moment coefficients. In addition, the values of maximum lift-drag ratio were increased approximately 5, 3, and 6 percent above those obtained with the symmetrically mounted bodies for the parabolic, Sears-Haack, and von Kármán bodies, respectively. The changes in cross-sectional-area development of the three semicircular body-wing combinations had little effect on the longitudinal aerodynamic characteristics.

INTRODUCTION

A continuing effort is being made by the National Aeronautics and Space Administration to develop efficient configurations for aircraft operating at supersonic speeds. From consideration of momentum theory and experiments, Eggers and Syvertson (ref. 1) have shown that flat-top wing-body combinations designed for Mach number 5.0 in which half-cone bodies are used may provide relatively high lift-drag ratios. Similar investigations were conducted (refs. 2 and 3) in which half-bodies of revolution that were designed for minimum wave drag at a Mach number of 5.0 were used, and these investigations also showed promise of efficient performance for this type of vehicle.

*Title, Unclassified.

The present investigation has been undertaken at the Langley Unitary Plan wind tunnel to determine the aerodynamic characteristics of several flat-top wing-body configurations having three different body shapes designed for minimum wave drag at a Mach number of 3.0. The body shapes investigated were a parabolic body of revolution, a Sears-Haack body, and a von Kármán ogive body. The tests were conducted with both symmetrically mounted circular-section bodies and bottom-mounted semicircular-section bodies. The wing used in the investigation had an arrow planform that was determined from consideration of the flow fields generated by the bodies. The tests were conducted at a Mach number of 3.0 and at a Reynolds number, based on the wing reference chord, of 2.6×10^6. Angle of attack was varied from -4° to 11°.

SYMBOLS

The force- and moment-coefficient data are presented about the system of stability axes. The reference centers and reference planes are shown in figure 1.

c	wing reference chord, 10.625 in.
c_r	wing root chord, 21.25 in.
C_D	drag coefficient, Drag/qS
C_L	lift coefficient, Lift/qS
C_m	pitching-moment coefficient, Pitching moment/qSc
L/D	lift-drag ratio
M	Mach number
q	free-stream dynamic pressure, lb/sq in.
r	radius of half-bodies, in.
r_1	radius of symmetrical bodies, in.
S	total wing planform area, 318.816 sq in.
x	distance parallel to wing center line, in.
α	angle of attack of reference plane, deg

[redacted]

MODELS AND APPARATUS

Design Considerations

The bodies of revolution chosen were a parabolic body, a Sears-Haack body, and a von Kármán ogive body. The bodies were designed for minimum wave drag at a Mach number of 3.0 according to the criteria of reference 4.

The wing planform was designed with the apex coinciding with the nose of the body. The leading edge was swept so that it was sonic or slightly supersonic at $M = 3.0$. Furthermore, the remaining part of the wing was designed to have a practical span and to encompass only positive pressure coefficients generated by the body. Consideration of these criteria resulted in the selection of an arrow planform wing with a ratio of root chord to body length of 0.74. Properties of the flow fields generated by the bodies were computed by the method of characteristics using a $1/4^{\circ}$ net.

Models and Instrumentation

Details of the arrow wing with bodies of circular and semicircular sections are shown in figure 1. The geometric characteristics of the models are as follows:

Bodies:	
Length, in.	28.75
Base area, sq in.	12.096
Wing:	
Area, sq in.	318.816
Span, in.	30.00
Root chord, in.	21.25
Aspect ratio	2.82
Taper ratio	0
Sweepback of leading edge, deg	65.5
Sweepback of trailing edge, deg	37.9
Total length in streamwise direction, wing apex to wing tip, in.	32.91
Mean aerodynamic chord, in.	14.17
Mean-aerodynamic-chord location, in.:	
Lateral distance from body center line	2.49
Longitudinal distance from apex	5.52
Notch ratio, Root chord/Total length of wing	0.65

Ordinates for the bodies are given in table I. The wing had a 2.5-percent-thick diamond-shaped streamwise thickness distribution with the maximum thickness at the 50-percent-chord line.

Forces and moments on the model were measured with an internally mounted six-component strain-gage balance. The balance was attached by means of a sting to the tunnel support system. Provision was made to measure the base pressure acting on the bodies.

The tests were conducted in the high Mach number test section of the Langley Unitary Plan wind tunnel, which is a variable-pressure, continuous-flow tunnel. The test section is 4 feet square and approximately 7 feet long. An asymmetric sliding-block-type nozzle allows continuous variation of Mach numbers from about 2.3 to 4.7.

TEST CONDITIONS

The tests were conducted at a Mach number of 3.0, a stagnation pressure of 23.5 pounds per square inch absolute, and a stagnation temperature of 150° F. The resulting Reynolds number, based on the wing reference chord, was 2.6×10^6. The dewpoint, measured at stagnation conditions, was maintained below -30° F to assure negligible condensation effects. Angle of attack was varied from -4° to 11°.

Transition was fixed for all tests. The transition strips consisted of 1/8-inch-wide bands of No. 60 carborundum grains that were sparsely applied at 5 percent of the local streamwise chord.

CORRECTIONS AND ACCURACY

The maximum deviation of the local Mach number is ±0.015 from the average value given. Pressure gradients are sufficiently small; hence, no buoyancy correction is required.

Angular deviation of the airflow in the test section was evaluated by comparing the difference between the normal-force coefficients for tests with the model inverted and those for tests with the model upright. The angles of attack were adjusted to eliminate these differences. Corrections for balance-sting deflection due to aerodynamic loads has also been made to the angles of attack.

The data have been adjusted to the condition of free-stream static pressure on the base of the bodies.

Based upon balance accuracy and repeatability of data, it is estimated that the data are accurate within the following limits:

C_L	±0.002
C_D	±0.0005
C_m	±0.0005
α, deg	±0.1

RESULTS AND DISCUSSION

The aerodynamic characteristics of the arrow wing with the three bodies of circular and semicircular sections are presented in figures 2 to 4. Figure 2 is

[redacted]

for the parabolic body of revolution, figure 3 for the Sears-Haack body, and figure 4 for the von Kármán ogive body. A comparison of the aerodynamic characteristics of the three body-wing configurations is presented in figure 5. These figures show that the lift and pitching-moment variations for all configurations are similar and are reasonably linear. However, for each configuration, changing from a symmetrically mounted circular-section body to a bottom-mounted semicircular-section body resulted in a substantial positive increment in lift coefficient as well as a positive increment in pitching-moment coefficient. In addition, as a result of the positive shift in lift, the drag due to lift was reduced and the maximum values of lift-drag ratio increased for the bottom-mounted body arrangement. The increases in maximum lift-drag ratio were approximately 5, 3, and 6 percent above those obtained with the symmetrically mounted bodies for the parabolic, Sears-Haack, and von Kármán bodies, respectively.

A comparison of the aerodynamic characteristics in pitch of the three semicircular body-wing model combinations (fig. 5) indicates little effect of small changes in cross-sectional-area development on the stability and performance characteristics of these models at a Mach number of 3.0.

Langley Research Center,
National Aeronautics and Space Administration,
Langley Station, Hampton, Va., April 4, 1963.

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2. Syvertson, Clarence A., Wong, Thomas J., and Gloria, Hermilo R.: Additional Experiments With Flat-Top Wing-Body Combinations at High Supersonic Speeds. NACA RM A56I11, 1957.

3. Migotsky, Eugene, and Adams, Gaynor J.: Some Properties of Wing and Half-Body Arrangements at Supersonic Speeds. NACA RM A57E15, 1957.

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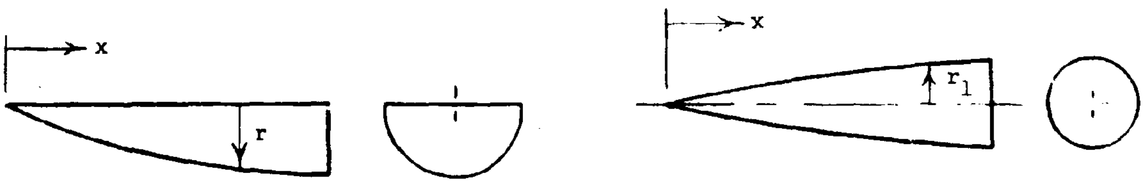
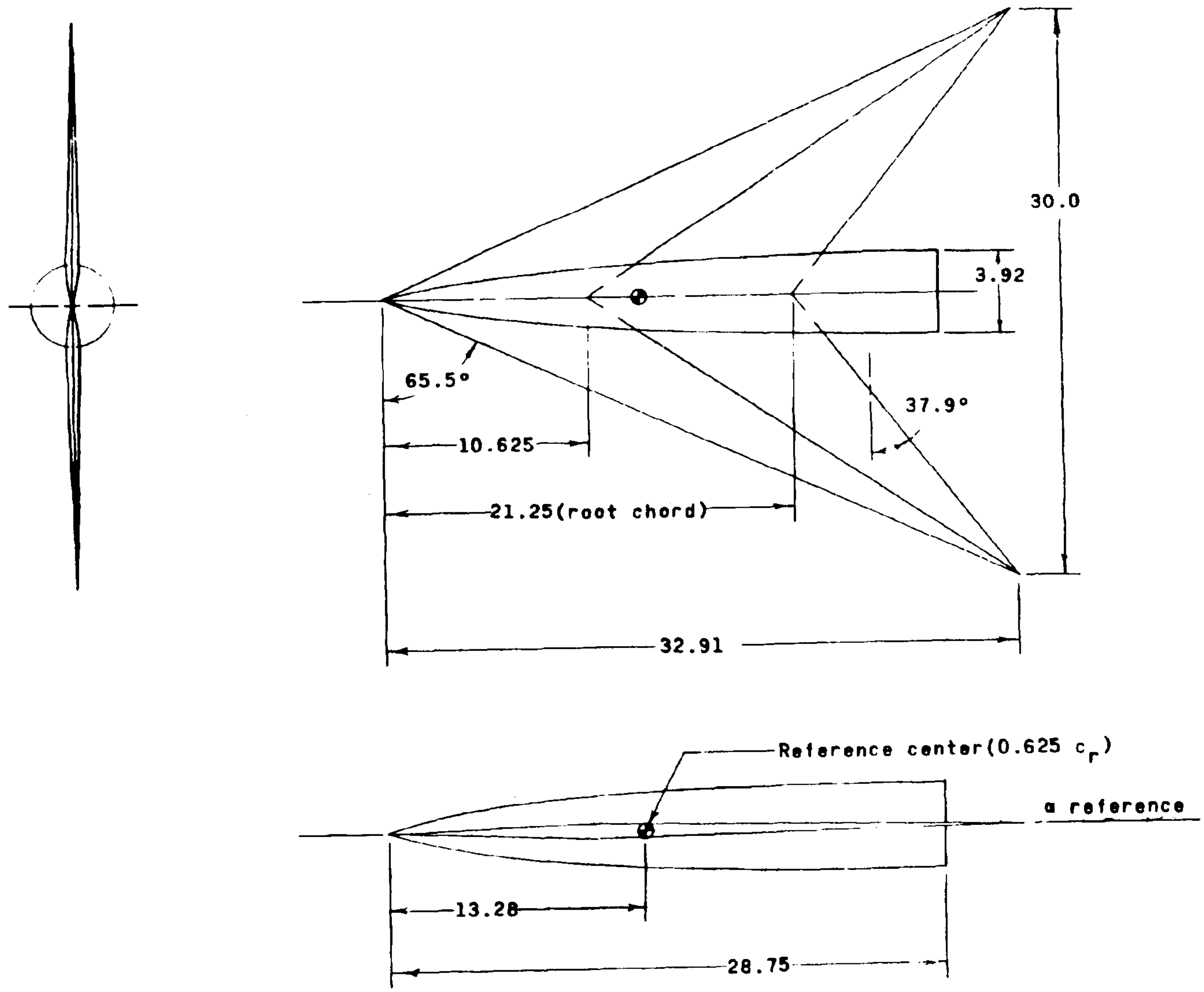
TABLE I.- BODY DESIGN COORDINATES



Parabolic body		
x	r	r_1
1.44	0.27	0.19
2.91	.54	.38
4.31	.77	.54
5.83	1.01	.71
7.62	1.27	.90
8.79	1.44	1.02
10.27	1.63	1.15
11.49	1.77	1.25
12.96	1.94	1.39
14.84	2.12	1.50
15.97	2.22	1.57
17.26	2.33	1.65
18.77	2.43	1.72
20.55	2.55	1.80
21.60	2.59	1.83
22.71	2.65	1.37
24.01	2.69	1.90
25.44	2.73	1.93
27.06	2.76	1.95
28.75	2.77	1.96

Sears-Haack body		
x	r	r_1
1.00	0.28	0.20
1.44	.38	.27
2.00	.49	.35
2.26	.67	.47
2.91	.80	.57
3.00	.82	.58
3.93	.99	.70
4.00	1.01	.71
5.00	1.17	.83
5.91	1.31	.93
6.00	1.32	.94
6.90	1.45	1.03
7.00	1.46	1.04
8.00	1.59	1.13
9.00	1.71	1.21
9.84	1.81	1.28
10.00	1.83	1.29
12.00	2.03	1.43
14.00	2.20	1.55
14.39	2.23	1.58
16.00	2.34	1.66
18.00	2.47	1.75
20.00	2.58	1.28
22.00	2.65	1.88
22.54	2.67	1.89
24.00	2.70	1.91
26.00	2.73	1.93
28.00	2.76	1.95
28.75	2.77	1.96

von Kármán body		
x	r	r_1
1.00	0.28	0.20
1.44	.38	.27
2.00	.49	.35
2.29	.54	.38
2.98	.65	.46
3.00	.66	.46
4.00	.80	.57
4.05	.81	.57
5.00	.94	.67
6.00	1.07	.76
6.12	1.09	.77
7.00	1.20	.85
8.00	1.32	.93
9.00	1.43	1.01
9.53	1.49	1.05
10.00	1.54	1.09
12.00	1.74	1.23
13.88	1.91	1.35
14.00	1.92	1.36
16.00	2.10	1.48
18.00	2.26	1.60
20.00	2.39	1.69
20.52	2.42	1.71
22.00	2.49	1.76
24.00	2.58	1.83
26.00	2.66	1.88
28.00	2.74	1.94
28.75	2.77	1.96



(a) Circular body (typical).

Figure 1.- Sketch of an arrow wing with bodies of circular and semicircular sections. All dimensions are in inches unless otherwise noted.

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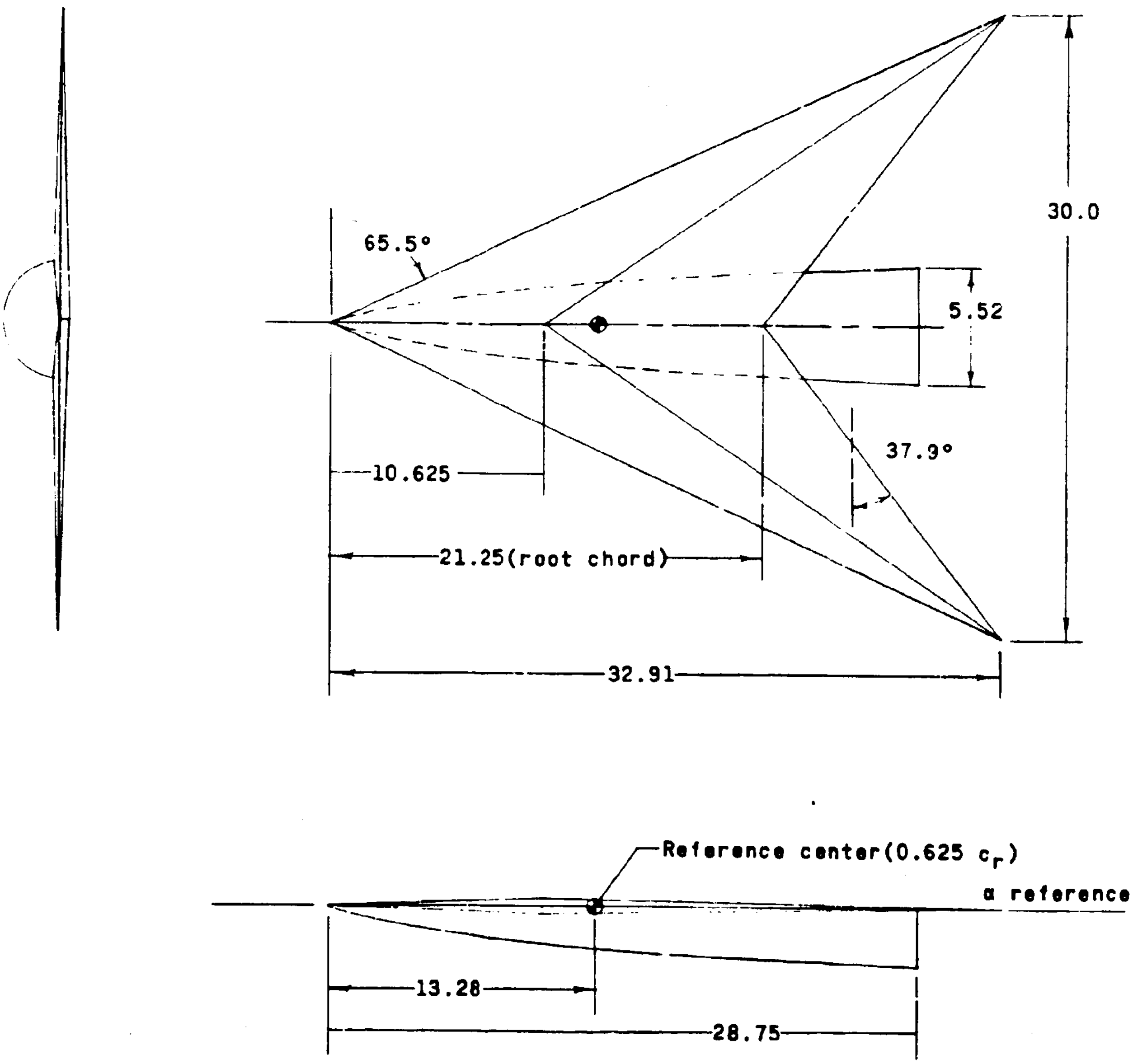

(b) Semicircular body (typical).

Figure 1.- Concluded.

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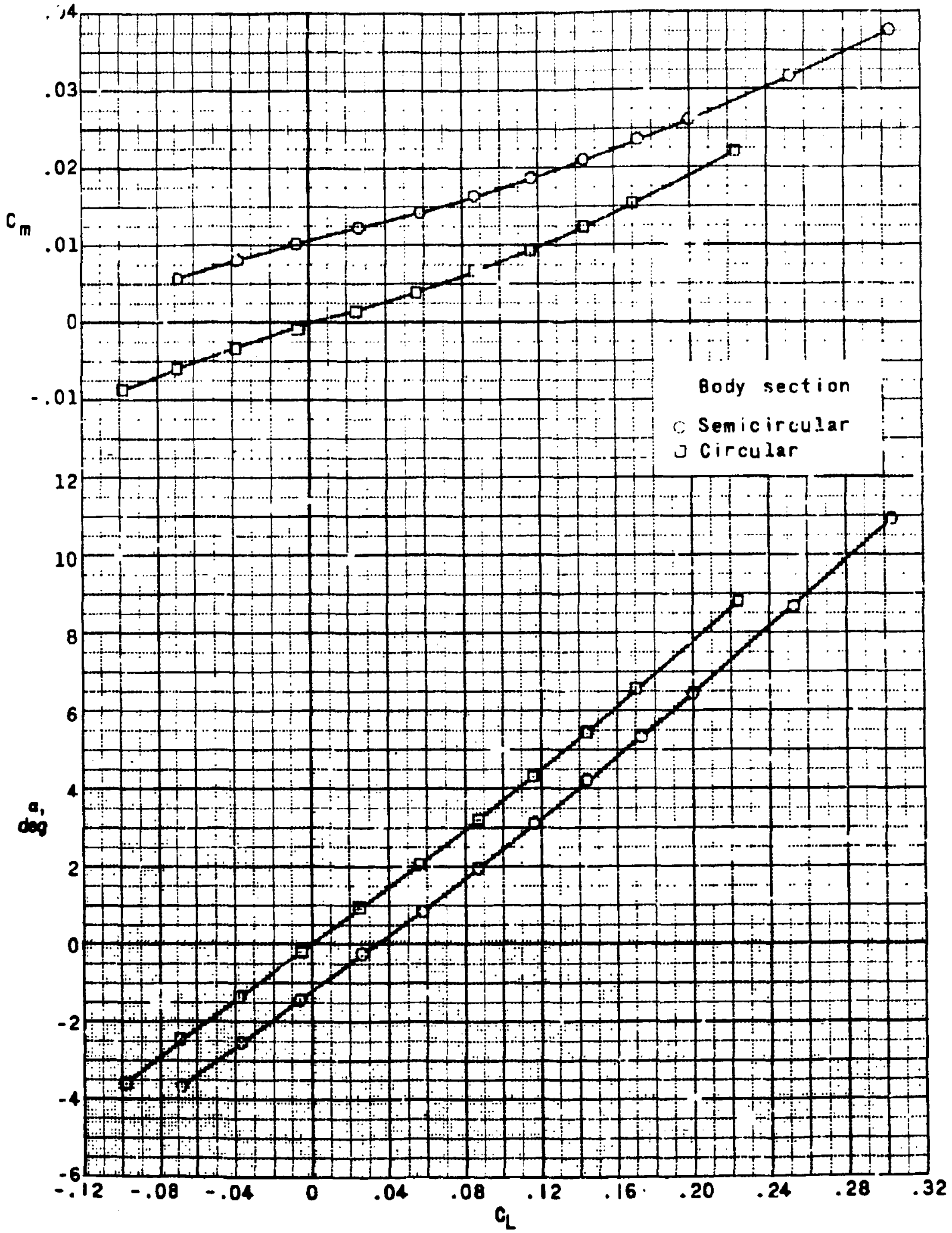

Figure 2.- Aerodynamic characteristics of an arrow wing with parabolic bodies of circular and semicircular sections.

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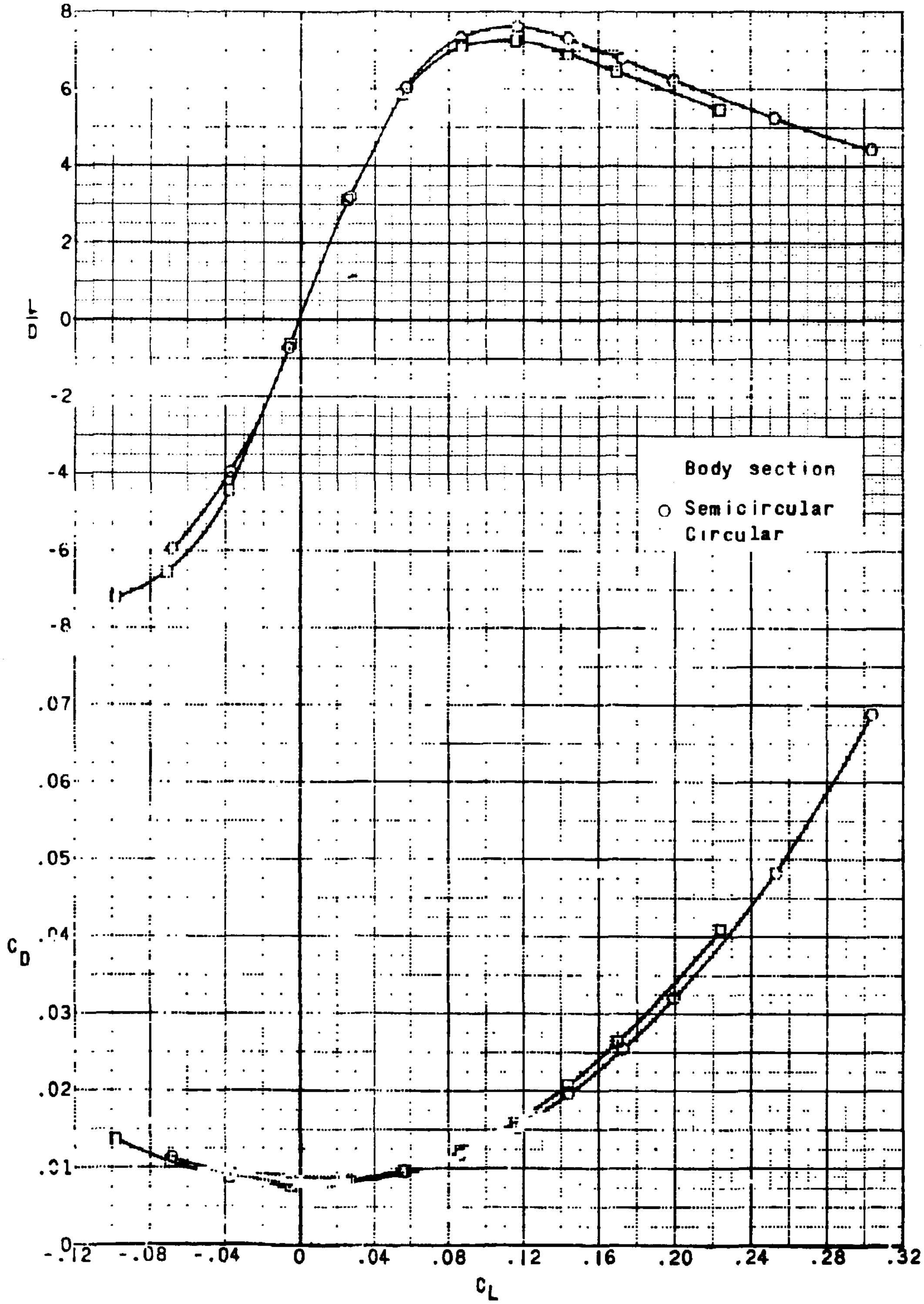

Figure 2.- Concluded.

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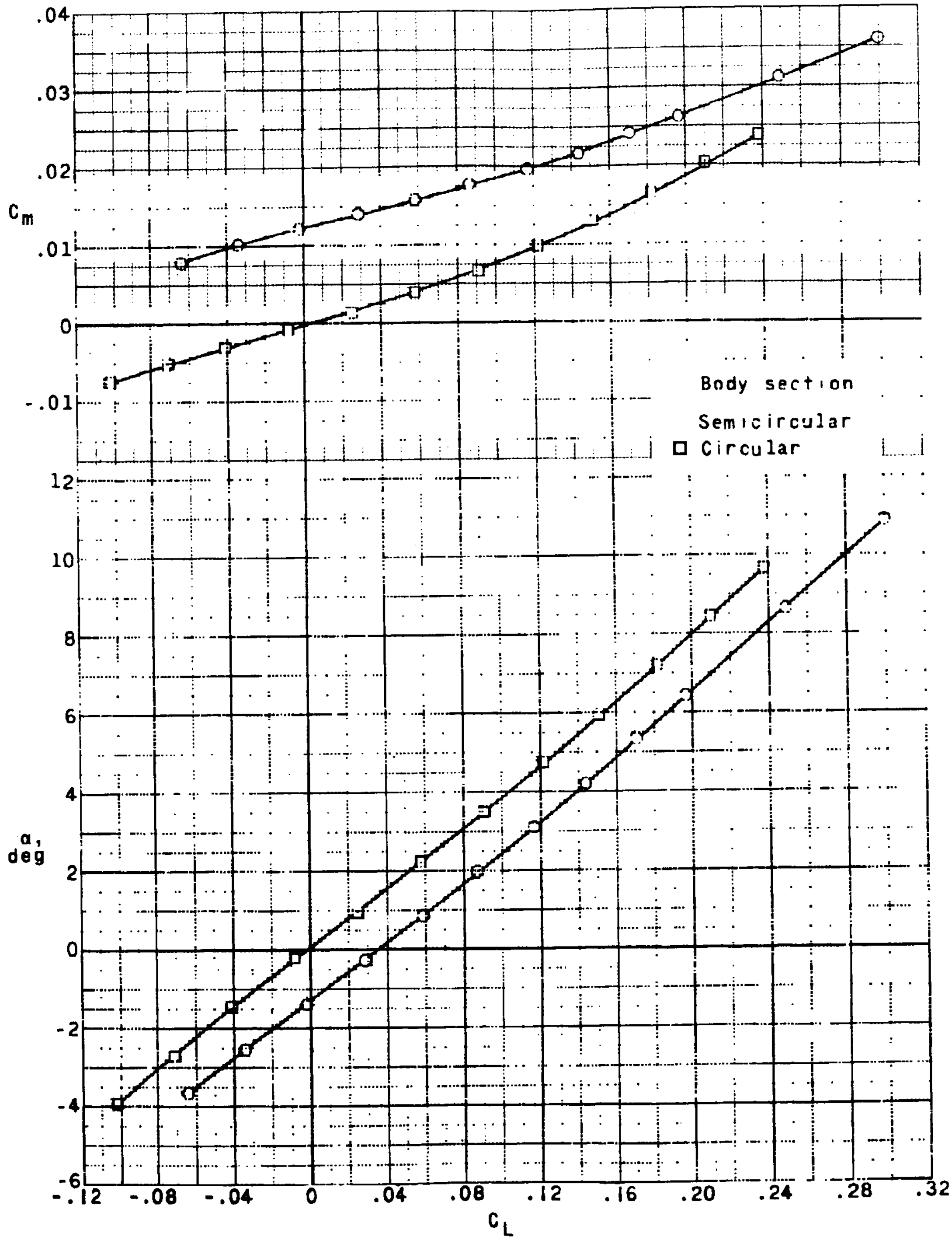

Figure 3.- Aerodynamic characteristics of an arrow wing with Sears-Haack bodies of circular and semicircular sections.

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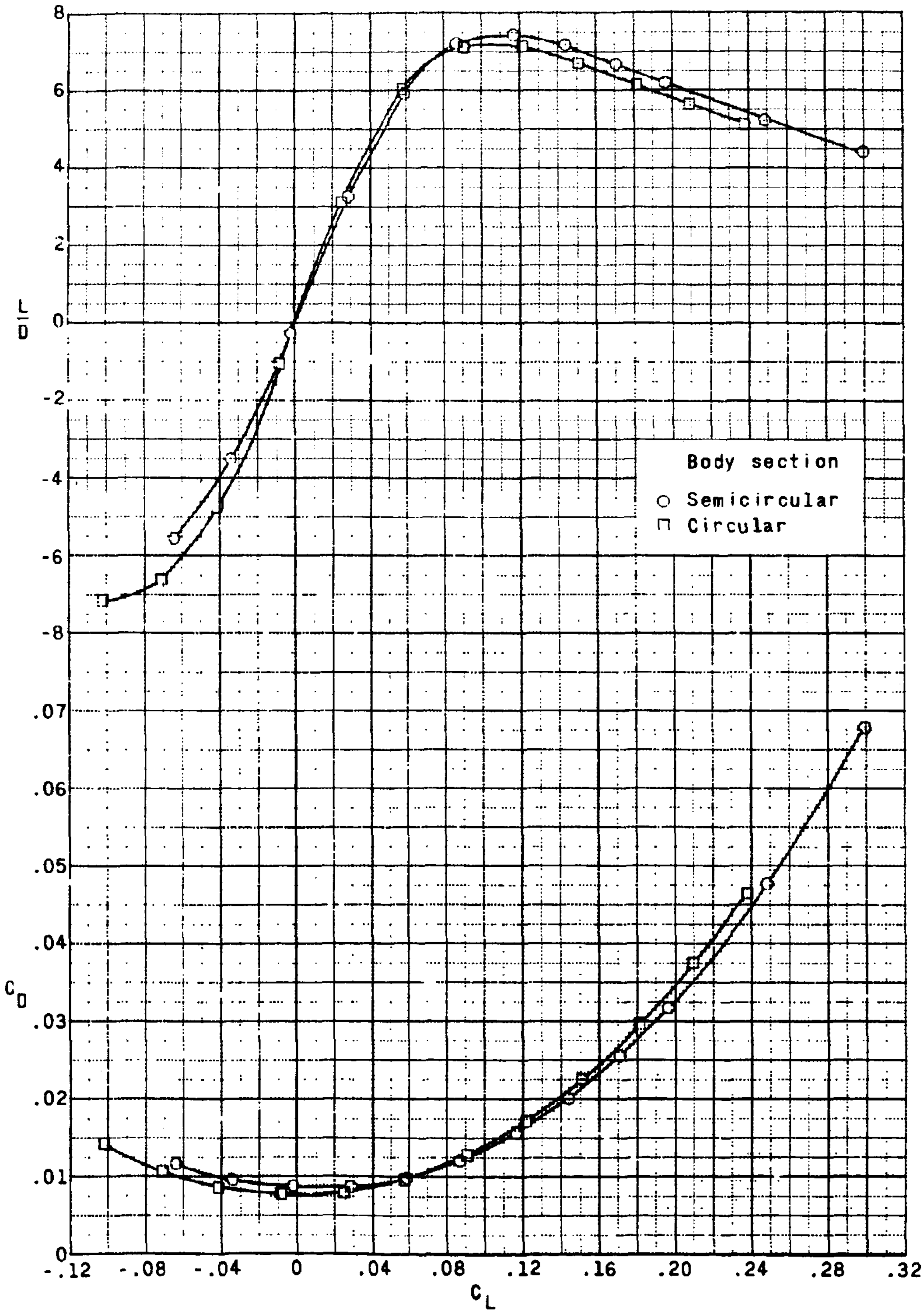

Figure 3.- Concluded.

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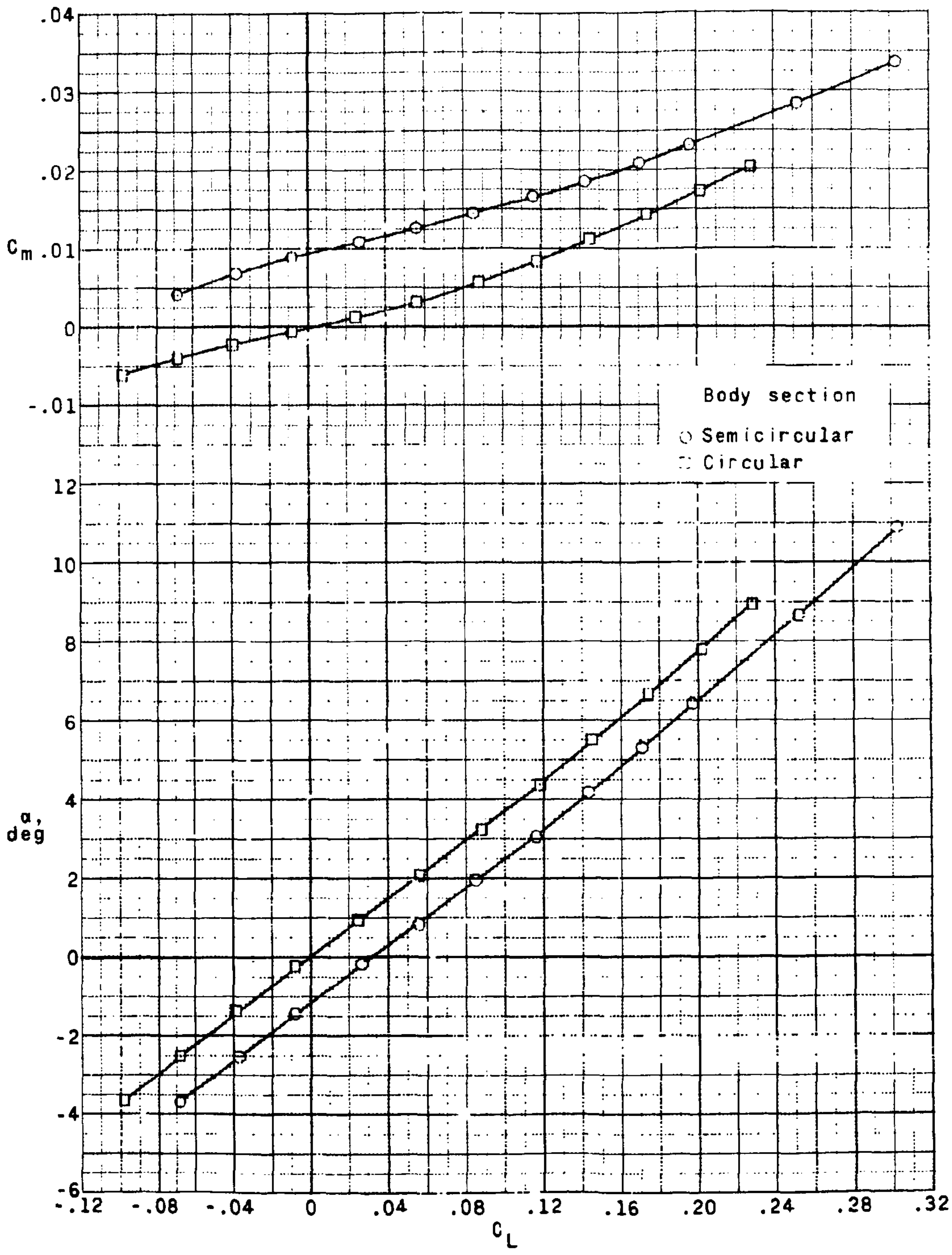

Figure 4.- Aerodynamic characteristics of an arrow wing with von Kármán bodies of circular and semicircular sections.

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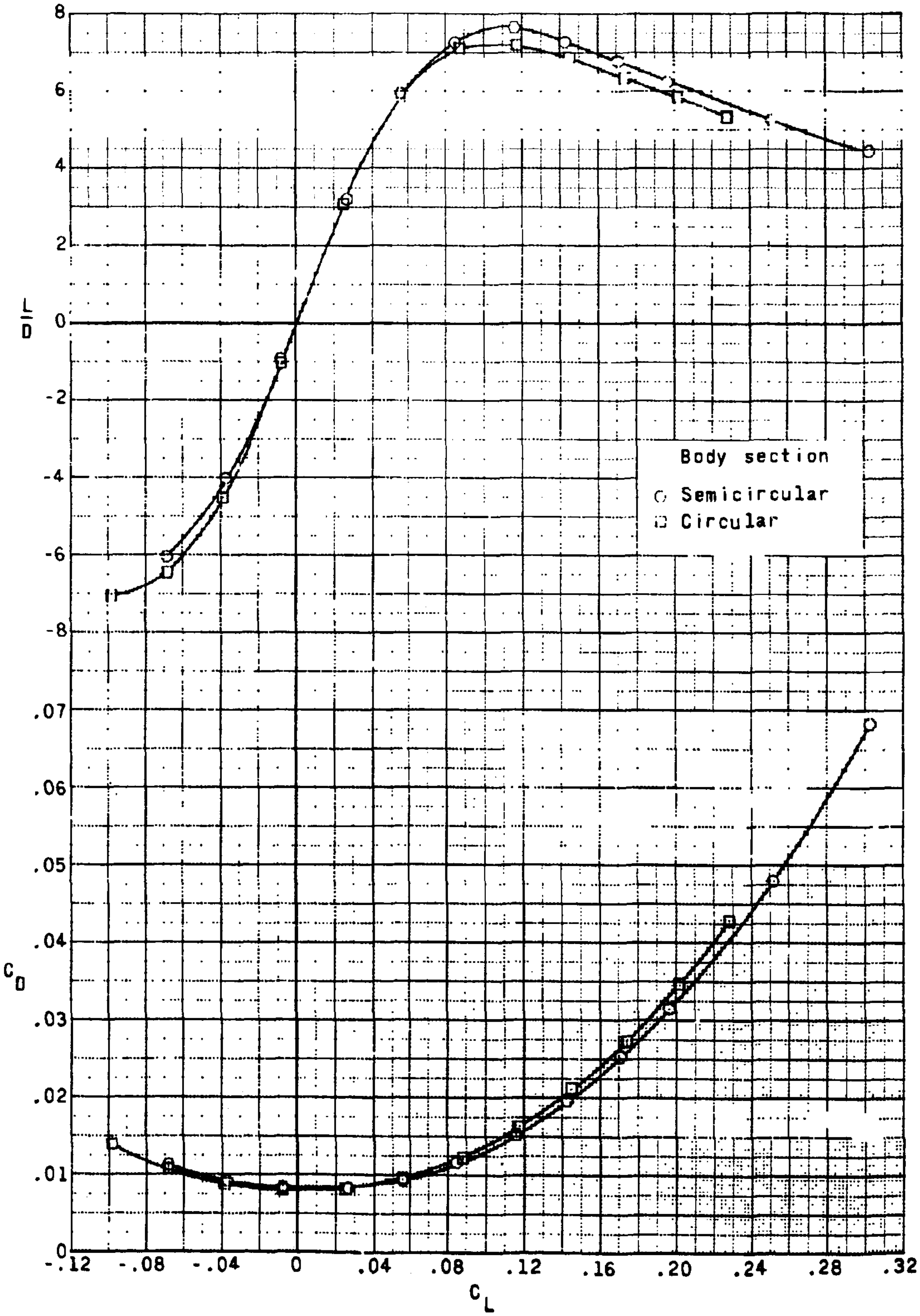

Figure 4.- Concluded.

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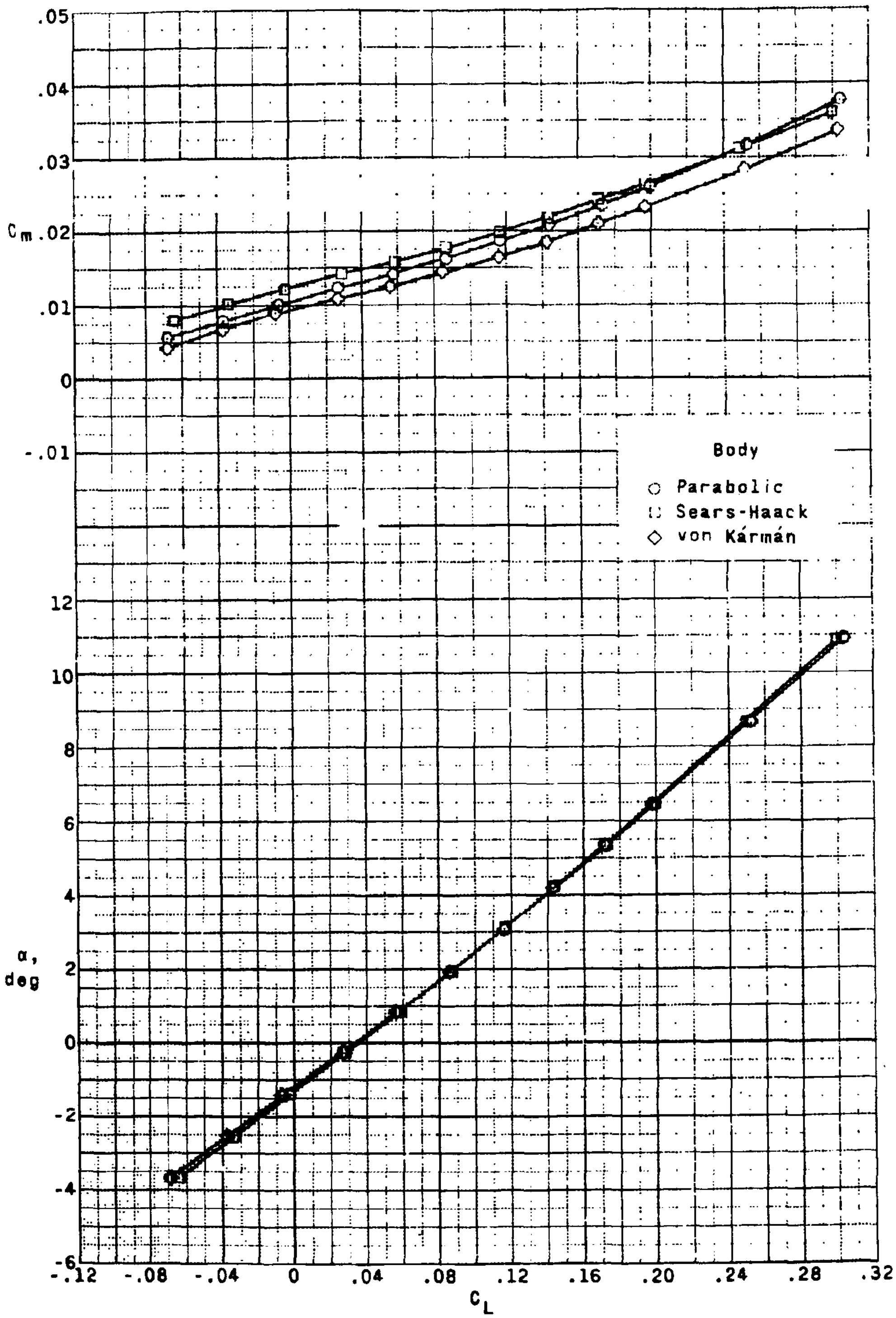

Figure 5.- Comparison of the aerodynamic characteristics of an arrow wing with bodies of semicircular sections.

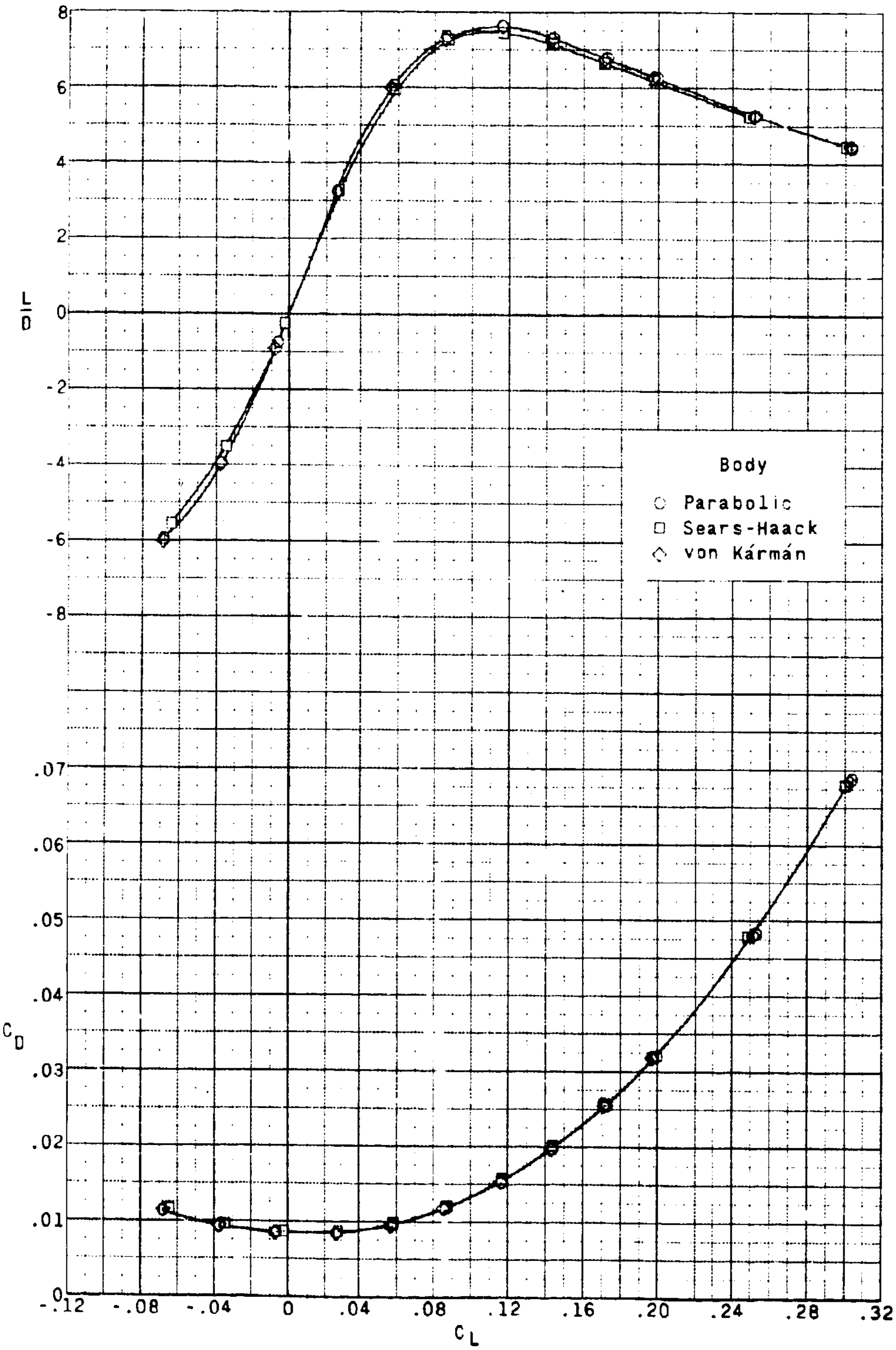

Figure 5.- Concluded.